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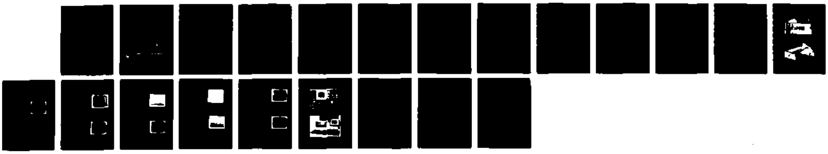

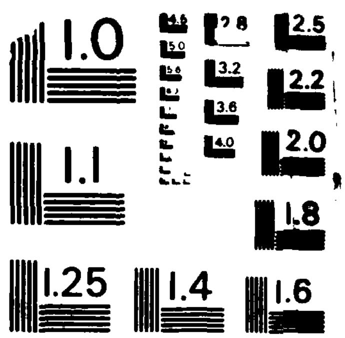
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TECHNICAL REPORT ARPAD-TR-87001

METHODOLOGY FOR VERIFICATION OF ULTRASONIC INSPECTION

EDWARD J. MIHOK

APRIL 1987

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18. SUPPLEMENTARY NOTES

This project has been accomplished as part of the U.S. Army's Materials Testing Technology Program, which has for its objective the timely establishment of testing techniques, procedures, and prototype equipment (in mechanical, chemical, and non-destructive testing) to ensure efficient inspection (over)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ultrasonic testing	Indirect reflectors
Verification	Artificial reflectors
Detection loop	Monitoring concepts
Pulse generator	MTT - Ultrasonic inspection
Direct reflectors	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is the result of a feasibility study for methodology for verification of ultrasonic inspection. Periodically, manufacturers of large caliber projectiles lost valuable time due to failure during calibration checkout of ultrasonic inspection systems, after which the bonded production was to be recalled for reinspection. Another reason for the development is the real probability that undetected failures of the systems between calibration checkout can exist. The methodology for verification of ultrasonic inspection provides a means for verification during and/or after inspection of (over)

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18. Supplementary Notes: (cont)

methods for material/materiel procured and maintained by AMC.

20. Abstract: (cont)

each part. Implementation of such methods yields immediate release of inspected parts for further processing.

Ultronsonic inspection systems that are presently operating have limited FAIL SAFE functions. The fail safe features in the present systems are ~~more~~ related to mechanical functions and operations ~~rather~~ than the most critical part, the ultrasonic flaw detection loop which includes the electronic system and the transducers. The only part of that system that is presently monitored is the pulser/receiver and only for as far as its operation is concerned. The effort addressed in this report concerns use of reflectors and electronic monitoring to assure proper system calibration during each inspection cycle.

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Per Ms. Florence Winkelman, ARDEC/SMCAR-MSI

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FIGURES

INTRODUCTION

This report is the result of a contractor provided feasibility study of methodology for real-time verification of ultrasonic inspection. The term "verification" defines the function of checking the ultrasonic equipment to assure that it is within proper calibration so that defective material would not be missed. The need for such development was recognized at the beginning of the implementation of ultrasonic inspection on large caliber projectiles. Periodically, manufacturers of such projectiles lost valuable time due to failure during verification of ultrasonic inspection systems, after which the bonded production has to be recalled for reinspection. Another reason for the development is the real probability that undetected failures of the systems between verifications can exist. The methodology of verification of ultrasonic inspection provides a means for verification during, before, or after inspection of each part. Implementation of such methods yields immediate release of inspected parts for further processing. The 155-mm M549 warhead was chosen as the test vehicle providing typical test situations for the project (fig. 1). The M549 test setup has both dynamic (scanning) and stationary channels.

DISCUSSION

Contractor Study

The contractor proposed that various direct and indirect signal reflectors and generators would be placed in several setups and studied for monitoring use. A direct signal reflector would be a target that the transducer would see at the beginning and/or end of a scan. An indirect target is the use of a particular feature of the part being inspected (e.g., the base corner). A signal generator is a device to generate direct sound waves that could be picked up by the inspection system for verification purposes. The generators were dropped early in the study as being costly, cumbersome to use, and not required. A detailed test program was presented along with notations on verifying flaw-gate function and providing for integration with a programmable gain control (PGC) curve. Hardware, software, and the use of a microprocessor were being considered in the proposed plans.

The following methods were suggested as most likely to be selected for investigation:

1. Dynamic transducer--PGC curve monitoring, GATE dimension monitoring, PULSER/RECEIVER monitoring, and TRANSDUCER alignment monitoring at end of scan using a direct artificial acoustic reflector.

2. Dynamic transducer--PGC curve monitoring, GATE dimension monitoring, PULSER/RECEIVER monitoring, TRANSDUCER alignment monitoring, and PART position monitoring using a natural boundary of the part (corner in the base of the projectile) as an indirect acoustic reflector.

3. Stationary transducer--GATE dimension monitoring, PULSER/RECEIVER monitoring, TRANSDUCER alignment monitoring, and PART position monitoring using an indirect artificial acoustic reflector.

4. Stationary transducer--GATE dimension monitoring, PULSER/RECEIVER monitoring, TRANSDUCER alignment monitoring, and PART position monitoring using the surface of the part as a direct acoustic reflector.

The development consisted of two separate parts, the "Methods" for target detection (reflectors) and the "Breadboard" for pulse injection and monitoring. The first development consisted of the methods investigation of the use of reflectors, either artificial or natural, derived from the geometric boundaries of the part to be inspected. The artificial reflectors were constructed of a 0.062-inch diameter rod with flat reflecting face, supported by a simple manipulator.

Other equipment used for this investigation consisted of the following:

1. An ultrasonic immersion tank measuring 48 inches long X 30 inches deep, transparent on all sides, manufactured by Rompas, Costa Mesa, CA (fig. 2).

2. A three-axis ultrasonic transducer manipulator that provided three necessary motions of freedom, vertical axis, angle of incidence, and rotary angle motions, manufactured by Rompas.

3. A two-axis ultrasonic transducer manipulator carriage and bridge providing X and Y linear motions, manufactured by Rompas (fig. 3).

4. A part rotator, manufactured by Rompas

5. An ultrasonic flaw detector type UJ-reflectoscope, manufactured by Automation Industries, Inc.

6. An ultrasonic transducer 2.25 MHz, 1/2-in. diameter, flat focused, PZT-5A

7 A projectile warhead body type M549, 155 mm with one longitudinal and one circumferential notch (0.035 inch deep) in the bourrelet and two drilled holes in the base, manufactured by N.I. Industries, Inc.

Methods for Target Detection

Circumferential notch or defect detection (fig. 4) shows the detection of the notch after one bounce of the ultrasonic test (UT) signal (one skip distance) through the wall of the projectile in the bourrelet area and the reflector after deflection of the beam off the outer diameter (o.d.) wall.

The angle of incidence with the o.d. surface is approximately 20 degrees in water, producing a shear wave with an angle of refraction of approximately 45 degrees in the steel. The reflector face of 0.062-inch diameter seems to be large as it produced a reflection with 10 dB higher amplitude than the reflection from the notch.

The signal reflected from the first or near corner A, at its maximum amplitude is shown in figure 5. A spreadout signal from corner B also appears at a lower amplitude. As the flat-faced transducer is scanned farther toward the

corner, the center of the beam passes A and reaches B producing a lower indication from A and higher from B (fig. 6).

Reflections from the thread will be obtained at 1/2 and 1 1/2 skip distances when scanning towards the nose of the projectile (fig. 7). These defined indications can only be obtained from the first thread in the path of the sound beam. The indications will wander somewhat in time as the part is rotating and as a result of the pitch angle of the thread.

For longitudinal notch or defect detection, figure 8 shows the detection of the notch by means of skip distance through the wall of the projectile in the bourrelet area and the reflector after deflection off the o.d. wall.

For the base area, figure 9 shows the detection of the hole and reflector. Scanning towards the corner produces reflections from corners A and B (fig. 10). A reflection of the inside corner feature at drastically reduced sensitivity due to the strength of signal received is shown in figure 11.

Breadboard

The second area of development concerns the breadboard which is basically a pulse generator that will provide the pulses for injection into a receiver of an ultrasonic flaw detector. Pulses are needed to monitor the electronic behavior of the flaw-detection system. The necessity for such a device is the incomplete verification of total system functions which is obtained when only monitoring reflectors (natural or artificial).

Flaw-gate dimensions and programmed-gain curves are major functions in the system that are monitored every time the PGC-Zone changes during a scan. The pulse generator or ultrasonic pulse injector (UPI) (fig. 12) is a device that generates pulses that are controlled in time through a microprocessor and as programmed by an Erasable Programmable Read Only Memory (EPROM) with addressing from external position encoders.

The UPI was designed to interface with a Rompas computer controlled ultrasonic flaw-detection instrumentation and a motor driven scan system. The test console with manual and automatic control panel, ultrasonic pulse injector, and computer controller is shown in figure 13.

The UPI breadboard consists of three sections: pulse delay, pulse gain control, and input/output (I/O).

1. The pulse delay section programmatically sets the time for the pulse to appear after initiating the trigger signal by microprocessor. The end of this delay coincides with a gate that is selected for flaw monitoring. When the pulse injector is active, the pulser of the pulser/receiver is disabled and the counterchain starts counting down; the counters having been preset by the microprocessor.

2. The pulse gain control section sets the amplitude of the pulse by latching the data in D-type flip flops for the digital-to-analog converter. The nominal pulse amplitude can be adjusted into the ultrasonic flaw-detection receiver input.

3. The I/O section controls the activity of the pulse injector and the test system.

Two modes of operation are possible; the flaw-detection system can be tested by injecting a pulse at regular time intervals or by injecting a pulse or pulses at predetermined locations during the inspection of a part. The microprocessor measures (or observes) the time interval of an encoder input and can be used to determine where on the part a test should occur.

The contractor developed software and used a microprocessor coupled with the UPI breadboard to monitor and control signal level, gate position, instrumentation input/output and failures, transducer alignment, and power failures. A microprocessor programmed reliability test successfully monitored variously planned signal amplitudes, gate positions, etc. Although transducer misalignment and power failures were programmed for the test, a motor controller fault unexpectedly misdirected the transducer alignment of the angle of incidence, and the unprogrammed error was detected; an error printout occurred. Another time, the contractor building experienced an unplanned power failure which at restart produced the proper error printout on the microprocessor The unplanned mishaps provided additional confirmation of the reliability test performed for the verification checkout system.

The breadboard constructed for this project was wire wrapped, a method often used for design and prototype development to show functionality. Certain instabilities are often inherent in such a breadboard, particularly where wires carrying analog signals run near other wires potentially inducing crosstalk. Interconnection with other boards and modules using long wire leads is not advantageous. This together with critical adjustments in the circuitry, presented a worst case setup for reliability tests. Generally, the overall reliability test showed that verification of ultrasonic inspection is very feasible; monitoring can be done during and after inspection of the part.

CONCLUSIONS

The following conclusions have been drawn from the contractors efforts:

1. System verification is achievable on a real time basis by use of target detection and the injection and monitoring of known pulses to assure proper electronic processing.

2. Indirect reflectors (using a natural boundary of the part) provide better assurance than direct reflectors. Indirect artificial reflectors should be provided where no natural boundaries are present as with channels scanning for longitudinal defects in projectile side walls.

3. Pulser/receiver unit should be a digital system to perform the electronic verification. The majority of ultrasonic systems being used today are analog; therefore, it will be impractical or cumbersome to implement this technology on todays existing systems.

RECOMMENDATIONS

Although the technology to verify on a real time basis has been demonstrated, application to existing systems is not recommended due to the need for digital pulser receivers. It is recommended that any new ultrasonic systems designed be required to use digital pulser receivers as well as multiaxis stepmotor controlled transducer manipulators that can be programmed to scan. Based on this, the equipment may take full advantage of real time verification, therefore, eliminating the need for storage of material for long periods awaiting system verification and any possibility of part mixups (accepts/rejects).

In general, it is recommended that natural reflectors should be used where the part configurations allows. Where natural reflectors are not available, artificial reflectors may be used.

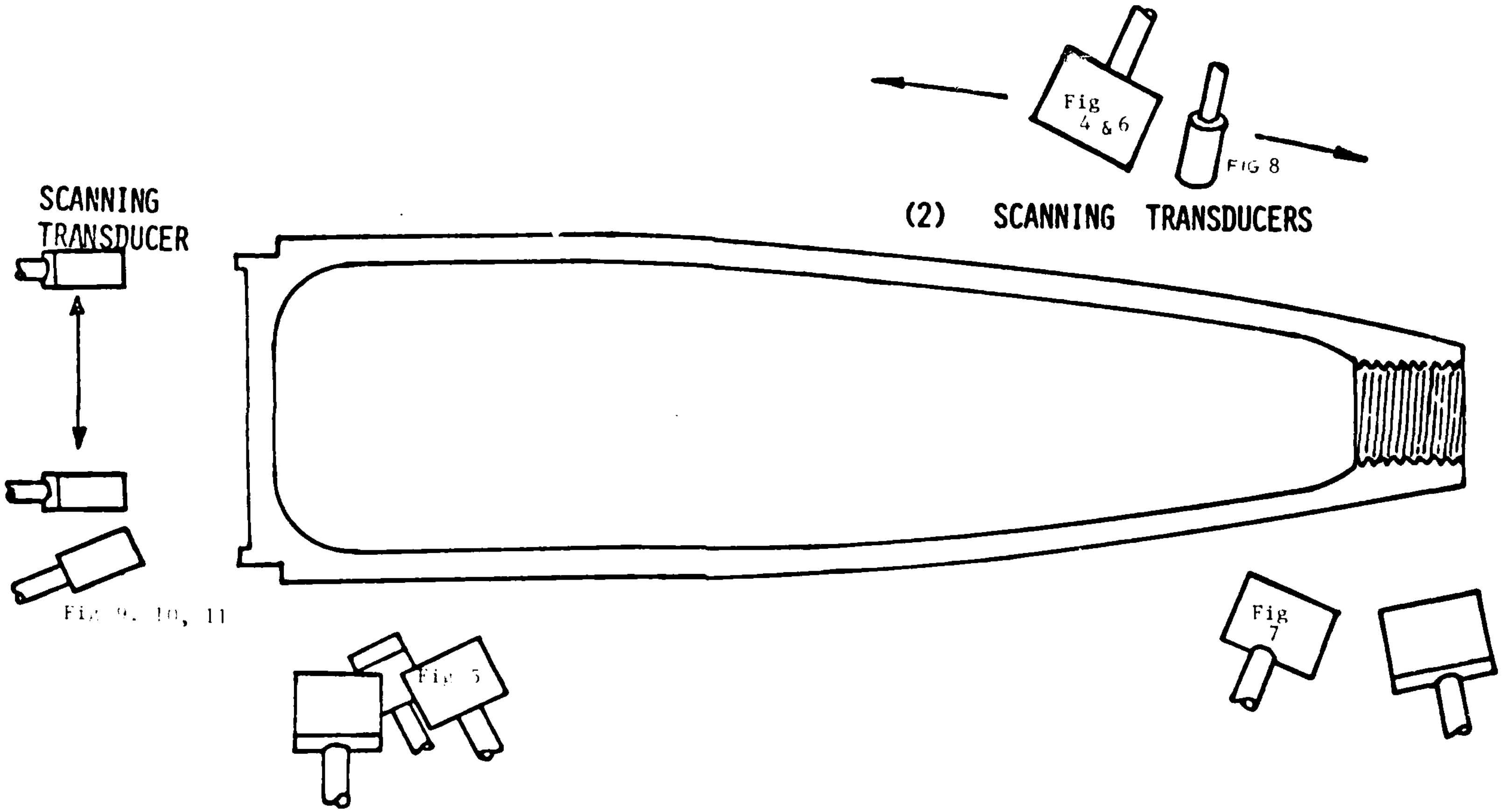


Figure 1. Ultrasonic transducer arrangement

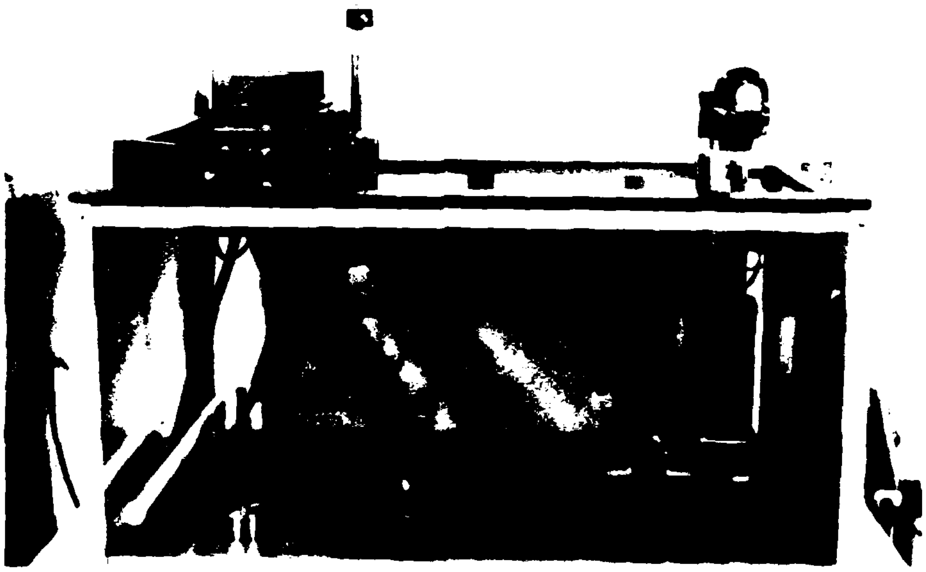


Figure 2. Ultrasonic immersion tank

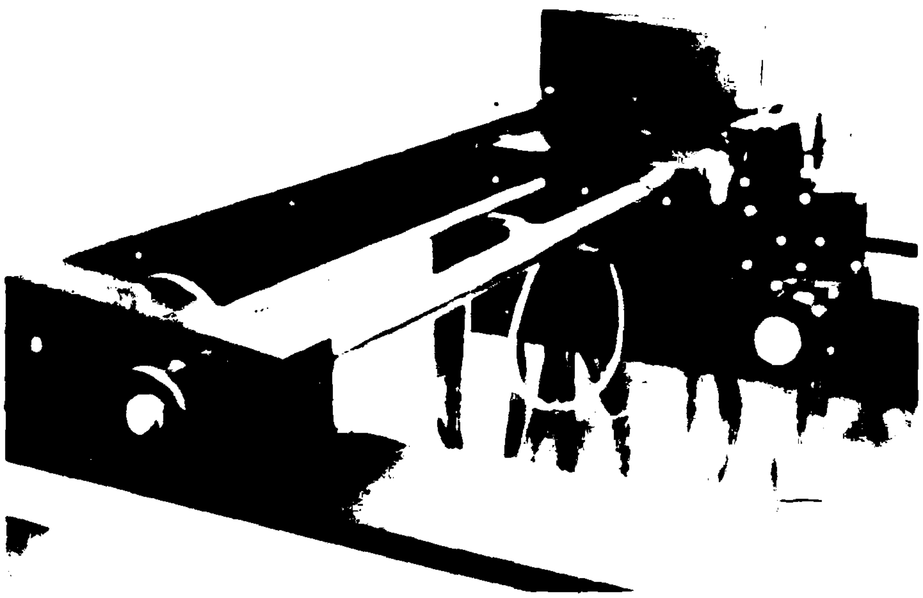


Figure 3. Ultrasonic manipulator w/auto control

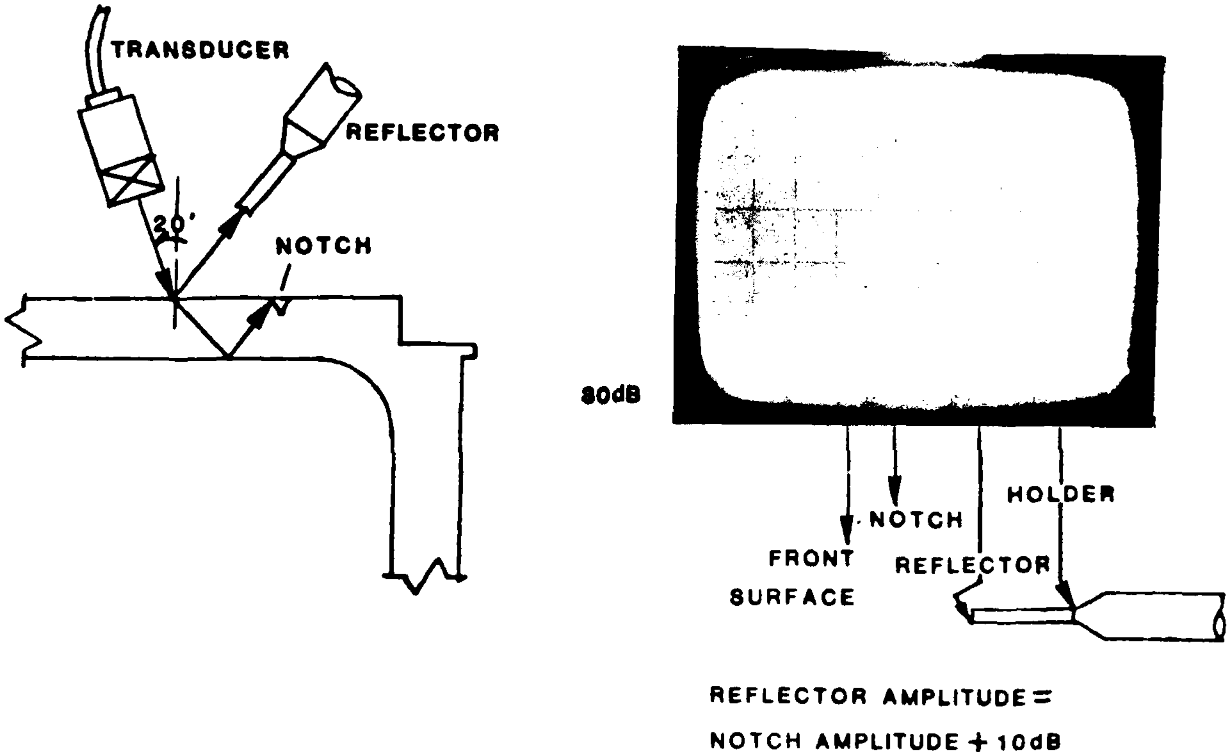


Figure 4. Artificial reflector and circumferential notch

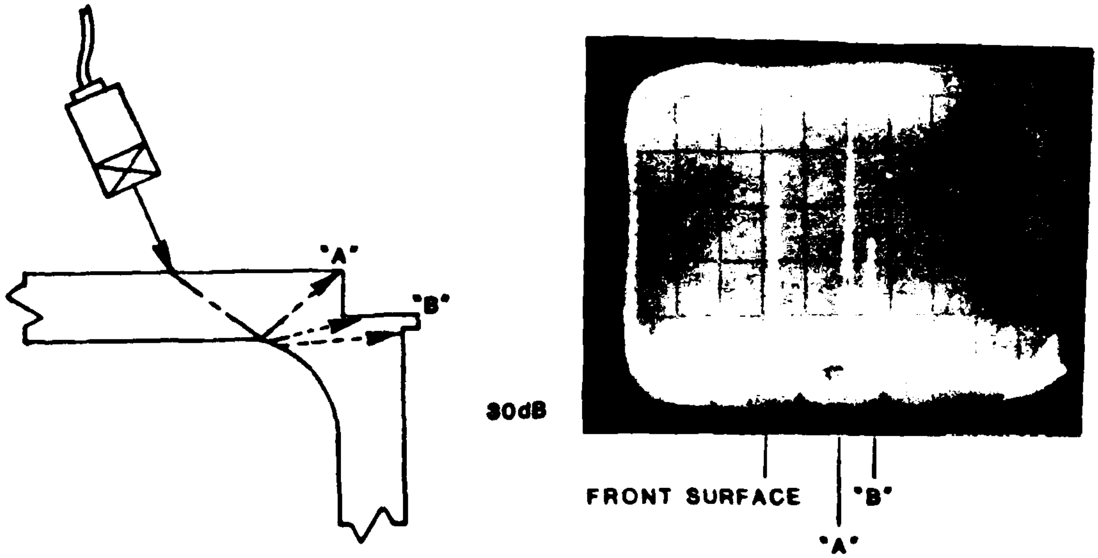


Figure 5. Part corner reflections

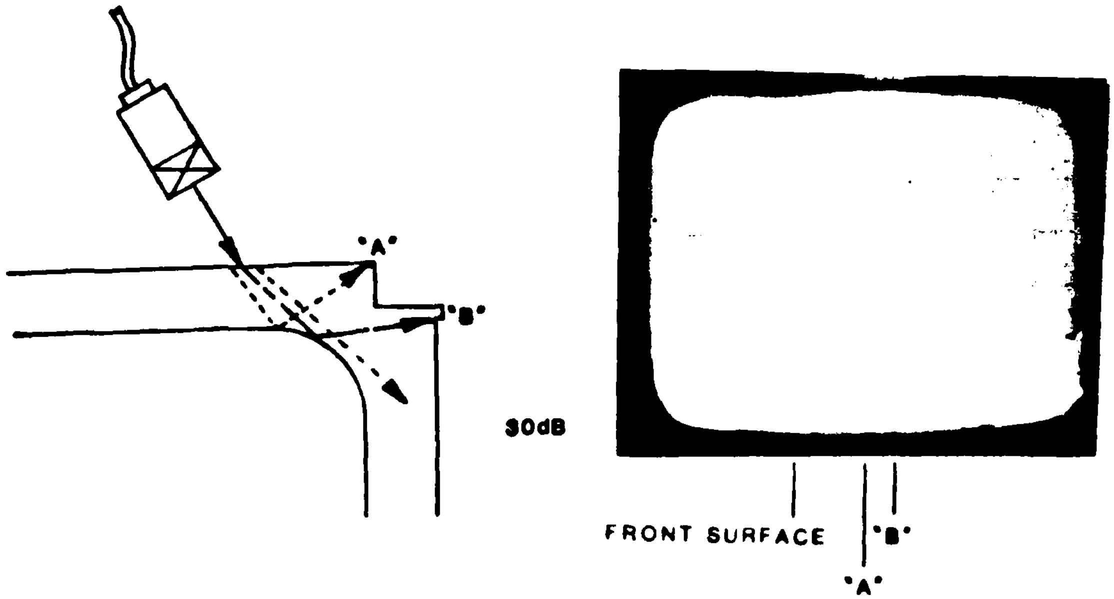
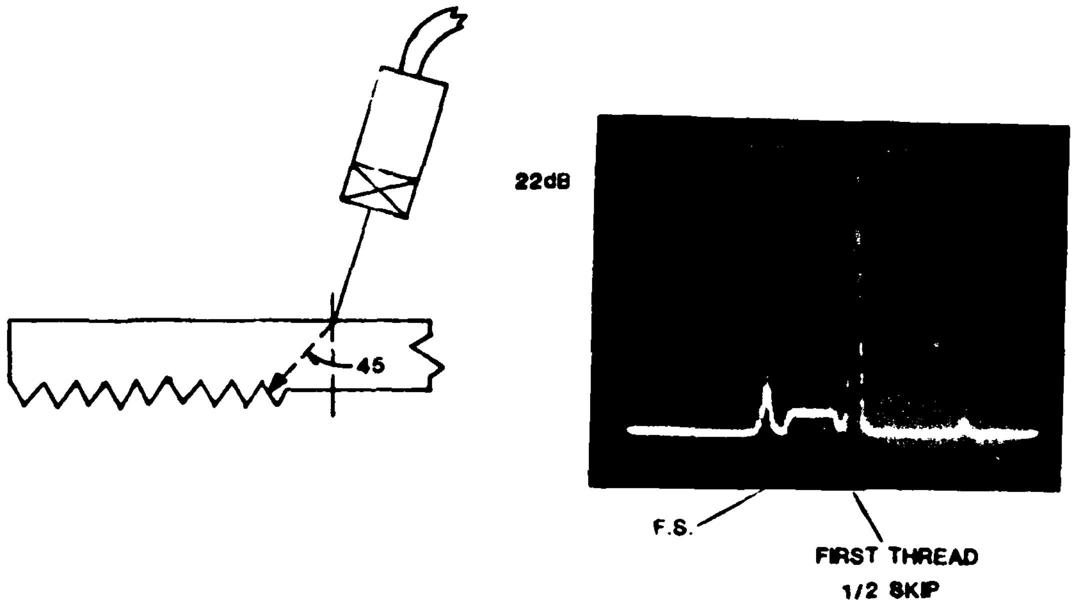
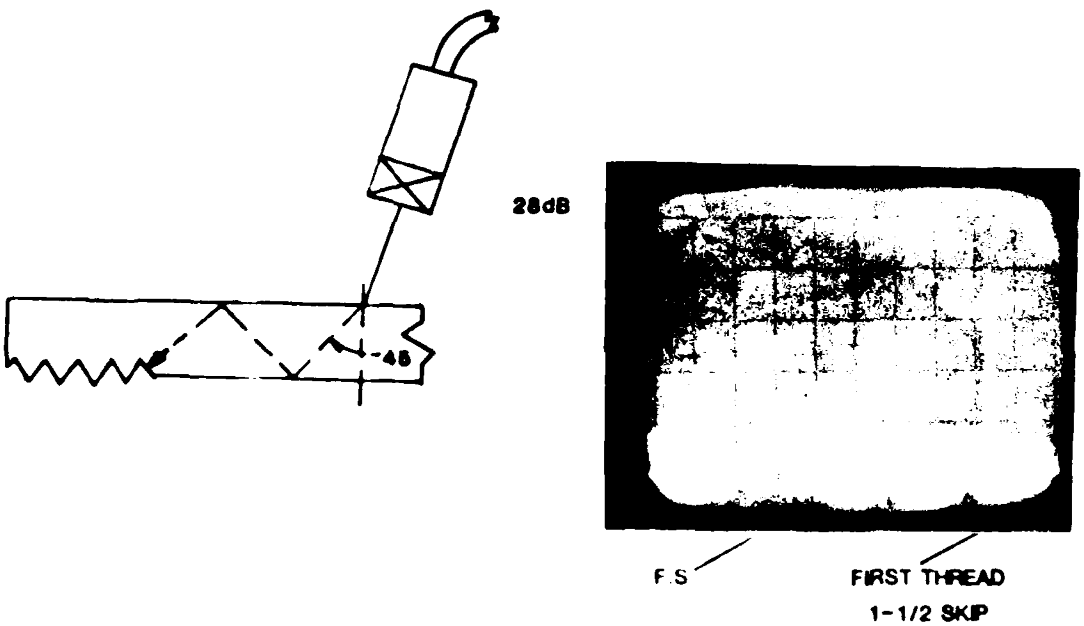


Figure 6. Continued scan of the part corner reflections



½ skip distance



1½ skip distance

Figure 7. Thread reflection

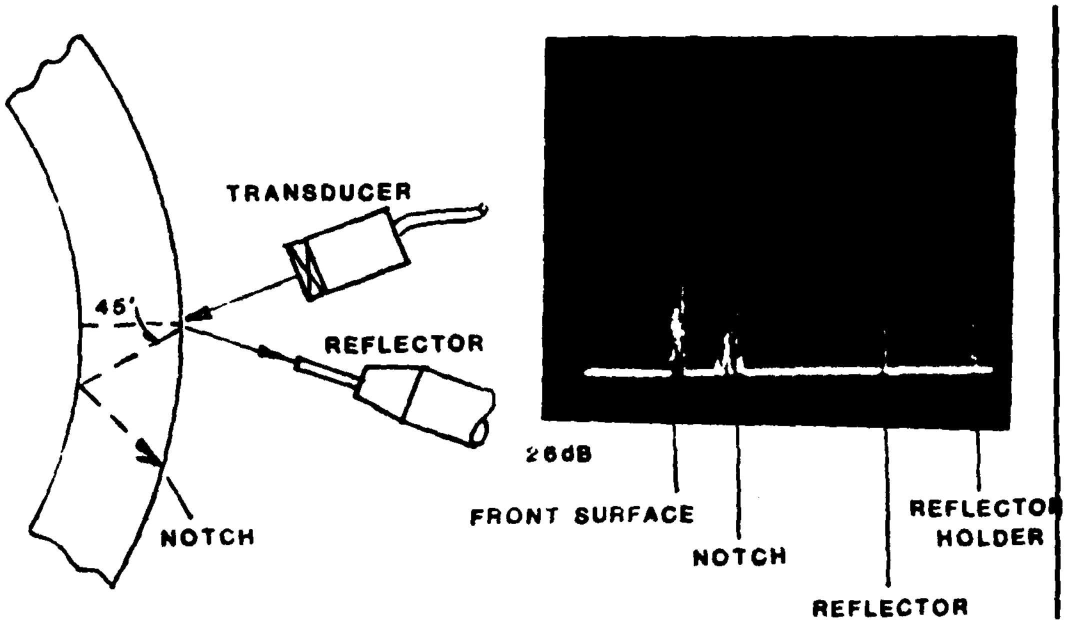


Figure 8. Artificial reflector and longitudinal notch

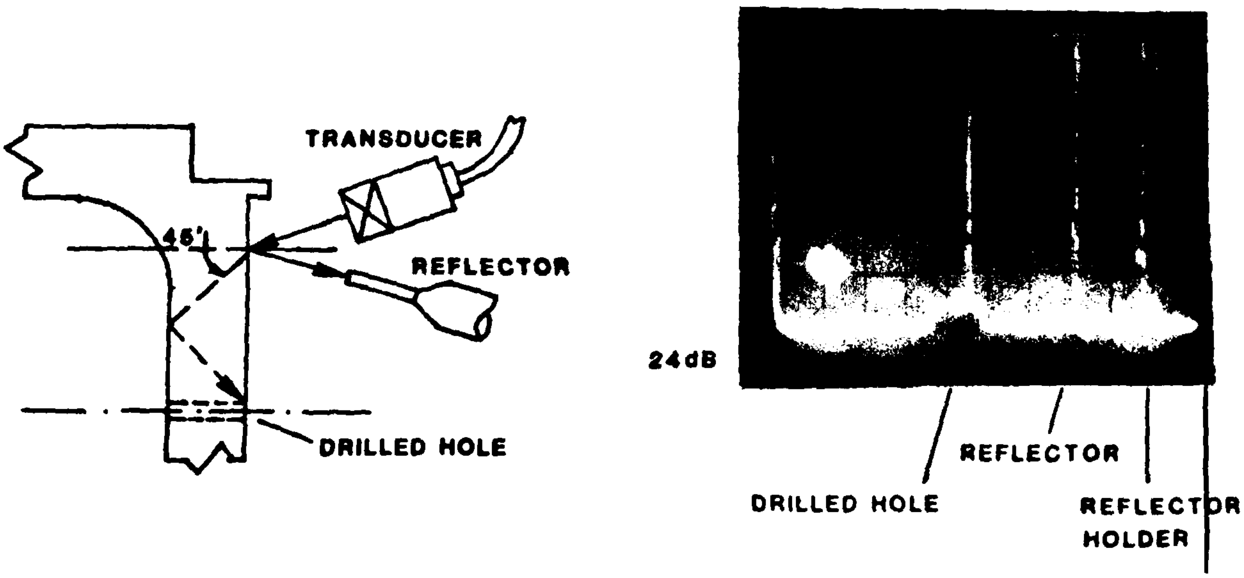


Figure 9. Drill hole and reflector in the base area

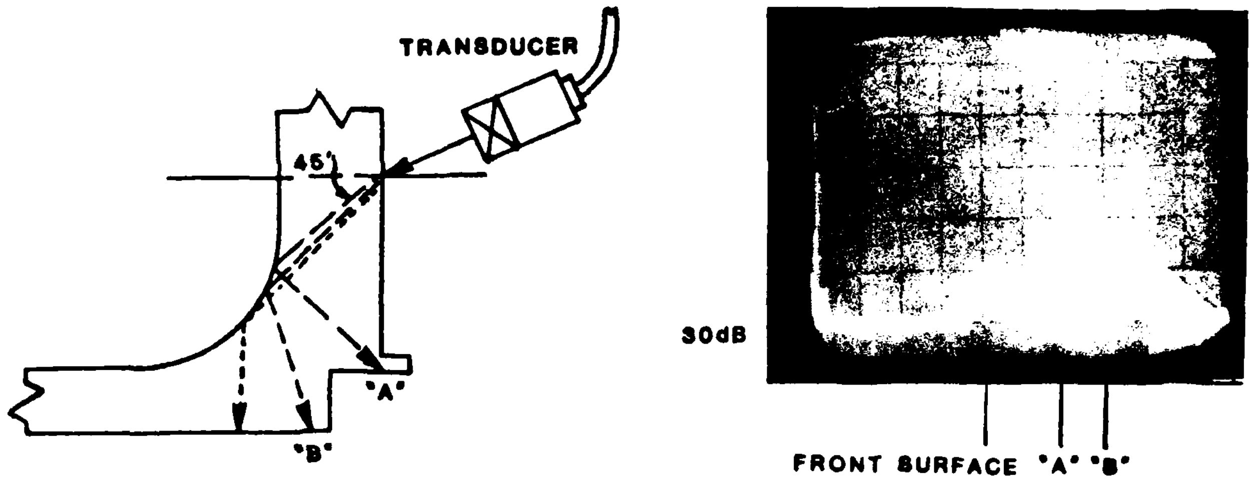


Figure 10. Corner reflections in the base area

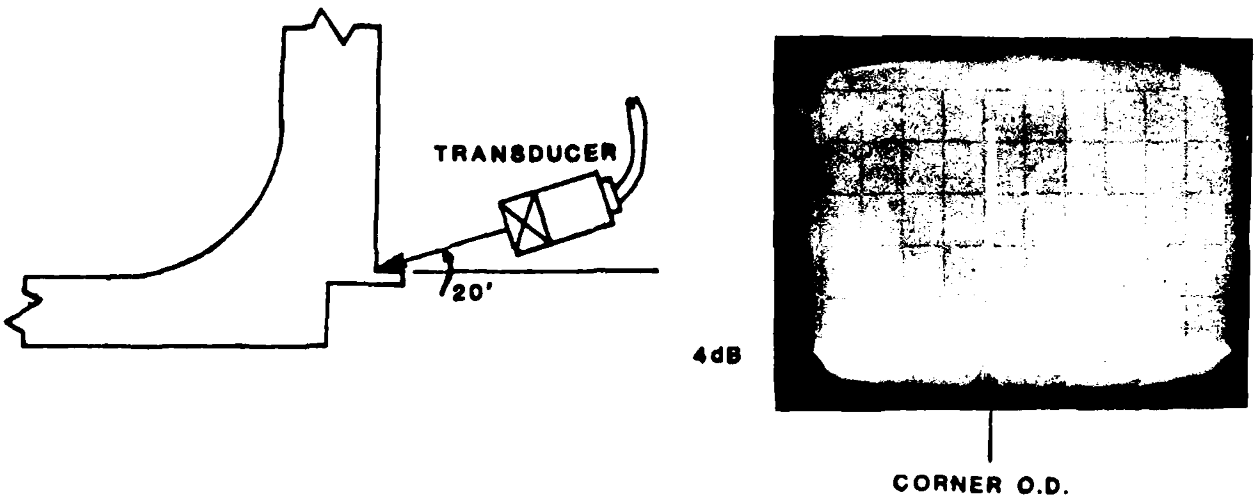


Figure 11. Outside corner reflection in the base area

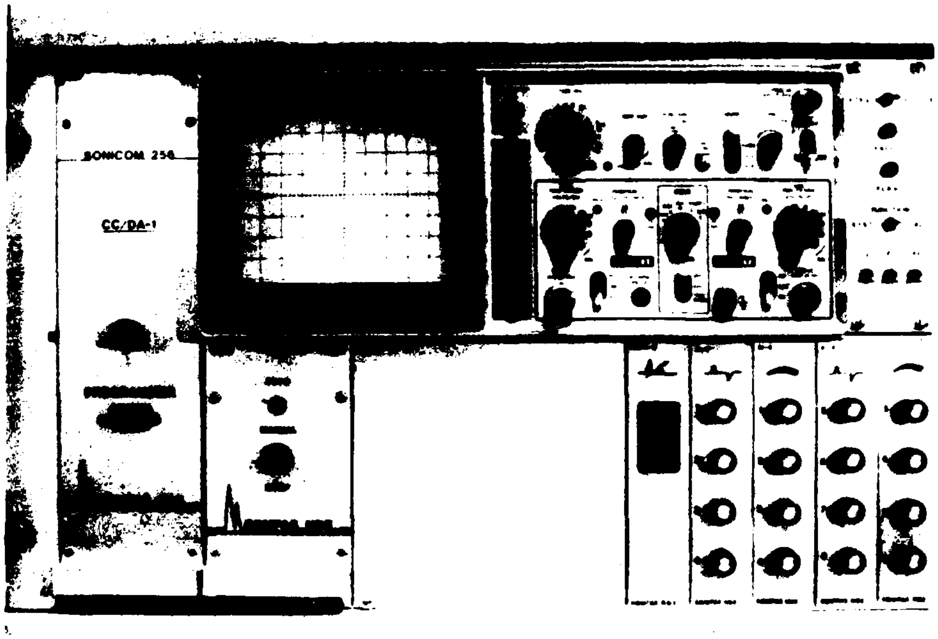


Figure 12. Ultrasonic pulse injector (UPI) module

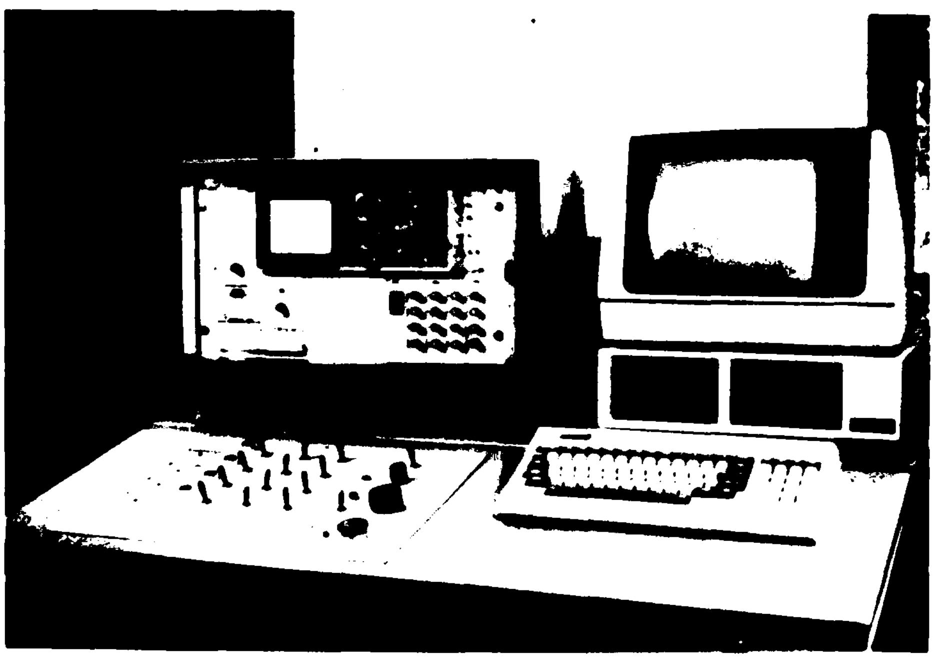


Figure 13. Test console

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